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Author Info

Nancy Duquet-Harvey	New Britannia Mine
Guy Deschenes	Scientist - Gold MMSL MTB, MMS

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PAPER 16

Plant Trial on the Industrial Control of Lead Nitrate at the New Britannia Mine

Nancy Duquet-Harvey[1] and Guy Deschenes[2]

[1] New Britannia Mine, Box 451, Snow Lake, Manitoba, Canada, R0B 1M0, Phone: (204) 358-2927, Fax: (204) 358-7601, email: metallurg@newbrit.com

[2] Mining and Mineral Sciences Laboratories, CANMET, Natural Resources Canada, 555 Booth Street, Ottawa, Ontario, Canada, K1A 0G1, Phone: (613) 992-0415, Fax: (613) 996-9041, email: gdeschen@nrcan.gc.ca

Key words : Lead nitrate, gold, control, leaching, New Britannia Mine, cyanide, oxygen, arsenopyrite.

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ABSTRACT

Lead Nitrate addition has been a part of the New Britannia Mine gold extraction process since 1997. Gold recoveries were increased from 89% in 1997 to 94% year to date, in part due to the incorporation of lead nitrate in the grinding circuit.

Because no direct measurement of lead in solution is possible, New Britannia Mine's method of controlling lead nitrate addition consists of using gold residues in #3 leach tank to predict the gold content of the final tail grade. The lead nitrate addition is then adjusted. Although a useful guide, thirty hours have passed before the rate of lead nitrate is changed.

From the consortium "Control of Lead Nitrate Addition in Gold Processing – An Industrial Application", a technology was developed to control the lead nitrate addition by tracking the levels of thiocyanate (CNS^-) in the leach solution. The determination of the reducing power is equivalent to the concentration of thiocyanate in the leach. Test work completed in laboratory showed promise. New Britannia Mine was then approached to test this method of control.

After two months of gathering baseline data, the decision was made to control the addition of lead nitrate using the measurement of thiocyanate. Within one week, the lead nitrate consumption was reduced by 30%. Two weeks later, it was reduced by a total of 50%. No detrimental effect was noticed on gold extraction. It is still in the evaluation stage since no instructions have been passed to operators for daily control. The results show potential. This paper presents some of the laboratory findings as well as preliminary plant trial results.

INTRODUCTION

The most common method used to control lead nitrate addition is based on the relationship between the gold content of the leach residue, the dissolved oxygen concentration and the free cyanide concentration of the leach solution (Deschênes, Lastra and Fulton 2002). The addition rate of lead nitrate is increased if the gold content of the leach residue is higher or if the cyanide consumption increases. This strategy creates fluctuations in the circuit and consequently profit loss.

Because the lead concentration is always very low in the leach solution (in general below 0.1 ppm), it is not possible to use the dissolved lead analysis to control its addition. One method to monitor the addition of lead nitrate in leaching is the "Prussian Blue test" which is used at Doyon Mine (Deschênes, Lastra and Fulton 2002). There is also a method that was used at Lupin Mine to determine the efficiency of the preaeration circuit (or pre-leaching). It is called the "reducing power method" (RPM) (Fulcher and Kim 1987). It was used at Lupin Gold Mines, which is presently shut down. The reducing power is determined by titration of the leach solution with potassium permanganate.

To be efficient, a method to control the lead nitrate addition has to be based on the analysis of the pulp to enable the operator to decide the lead nitrate addition rate before the detrimental effects of sulphide minerals reduce the efficiency of the leach. A project, sponsored by a consortium of

Australian, South African and Canadian gold producers, was initiated to develop a robust control method of the leaching circuit of gold plants. Positive results were obtained at the laboratory scale. The technology was the object of patent applications in Canada (Deschênes and Fulton 2002), in Australia and in South Africa. A plant trial was initiated at New Britannia Mine to test this technology. The main objective to improve the control of lead nitrate was to maintain the highest gold extraction in the cyanidation circuit in conjunction with reagents usage. This paper presents some of the findings of the project and the preliminary results of the plant trial.

Reducing Power Test for Cyanide Leachate

The reducing power (RP) provides a gross measurement of reducing substances present in a cyanidation leachate. These substances may variously represent:

- competitors for the dissolved oxygen needed for the dissolution of gold,
- consumers of cyanide, the critical ligand involved in dissolving gold, and
- cyanide degradation products, notably, thiocyanate.

A sample of the process solution is titrated with the strong oxidant potassium permanganate, under highly acidic conditions (approximately 1M H^+), to a persistent pink (permanganate-colour) end point. The procedure is: pipette 25 mL of leach solution into a 500 mL flask; add 150 mL of deionized water; add 25 mL of 25% (by volume) sulphuric acid and titrate with 0.02 M potassium permanganate solution until the end point (pink). The value of the reducing power = 40 x mL of $KMnO_4$ volume.

The visual titration uses a color end point. A potentiometric titration could also be used. In this work, a Brinkmann Metrohm Model 716 DMS Titrino automatic titration apparatus was used, applying Brinkmann Titrino Workcell Software, Version 4.2 for control and measurement. The equivalence point(s) were determined by the instrument software, as maxima in the slope of the E (platinum electrode voltage response) vs V (volume of titrant curve). In most cases, the equivalence points are closely associated with titrimetric end points.

The determination of reducing power by potentiometric titration provides measurements that can be interpreted in terms of concentrations of two major constituents associated with cyanidation, thiosulphate and thiocyanate. Titration of thiocyanate appears to occur concurrently to titration of thiosulphate, rather than successively. However, the equivalence points observed and their differences can be applied empirically to obtain semi-quantitative measurements.

The titrations appear to follow complex oxidation pathways, and the stoichiometries are not in accord with simple oxidation to sulphate. There is some evidence that the stoichiometries are somewhat different in the mixed systems than when the species are measured independently.

A typical potentiometric titration is presented in Figure 1. Because the equipment to conduct potentiometric titration is expensive ($Can12,000), a comparison was made between the manual titration and the potentiometric titration. The results are illustrated in Figure 2. According to this figure, in spite of the difference in the results, a manual titration gives acceptable results on the reducing power.

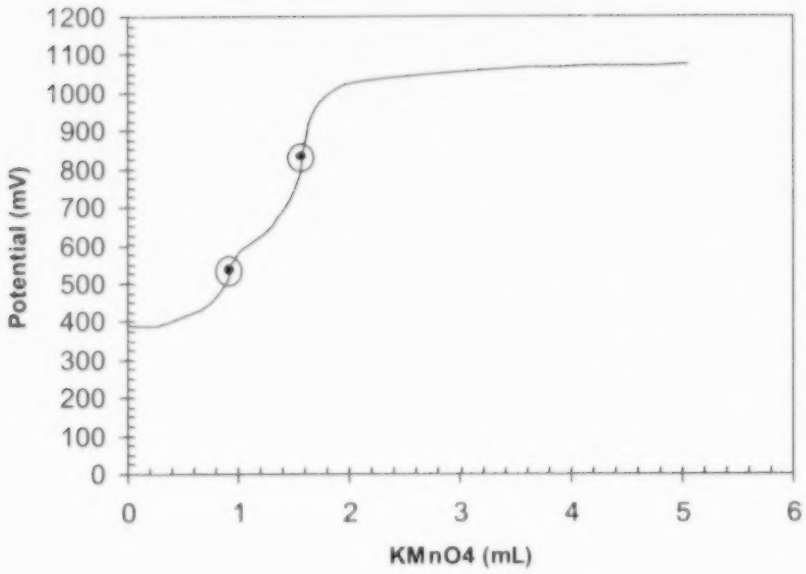

Figure 1: Potentiometric titration curve for the determination of thiocyanate using an automatic titrator

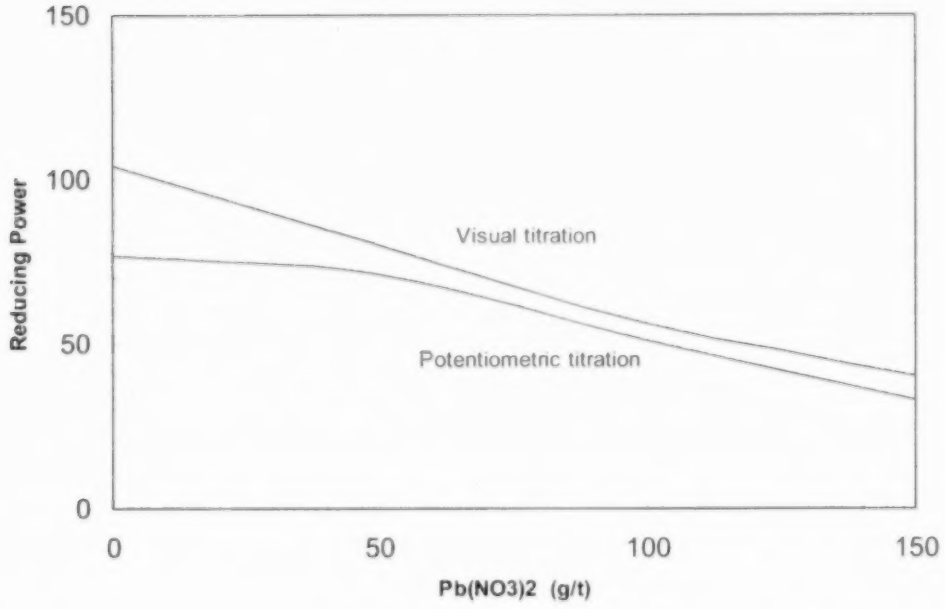

Figure 2: Comparison of potentiometric and visual titration for the measurement of the reducing power with various addition of lead nitrate. Cyanidation of the New Britannia Mine ore. Pre-leaching: pH 11.1, 8 ppm O_2, 0.5 h; cyanidation: pH 11.1, 230 ppm NaCN, 8 ppm O_2

Effect of Lead Nitrate on Cyanidation of a Sample of New Britannia Mine Gold Ore

The effect of lead nitrate addition on the gold dissolution kinetics of New Britannia Mine ore is illustrated in Figure 3. There is a significant increase in the gold leaching kinetics from 50 g/t to 100 g/t lead nitrate, but there is no additional improvement beyond the 100 g/t addition. The steady state is reached in 24 hours, at a 100 g/t lead nitrate addition, although it takes much longer for lower addition rates. However, the overall gold extraction is about the same, ~88.5%, for the three systems after 51 hours. The addition of lead nitrate also reduced the cyanide consumption by 14%. Indeed, cyanide consumption was 0.32 kg/t at 150 g/t $Pb(NO_3)_2$, compared to 0.37 kg/t with 50 g/t lead nitrate.

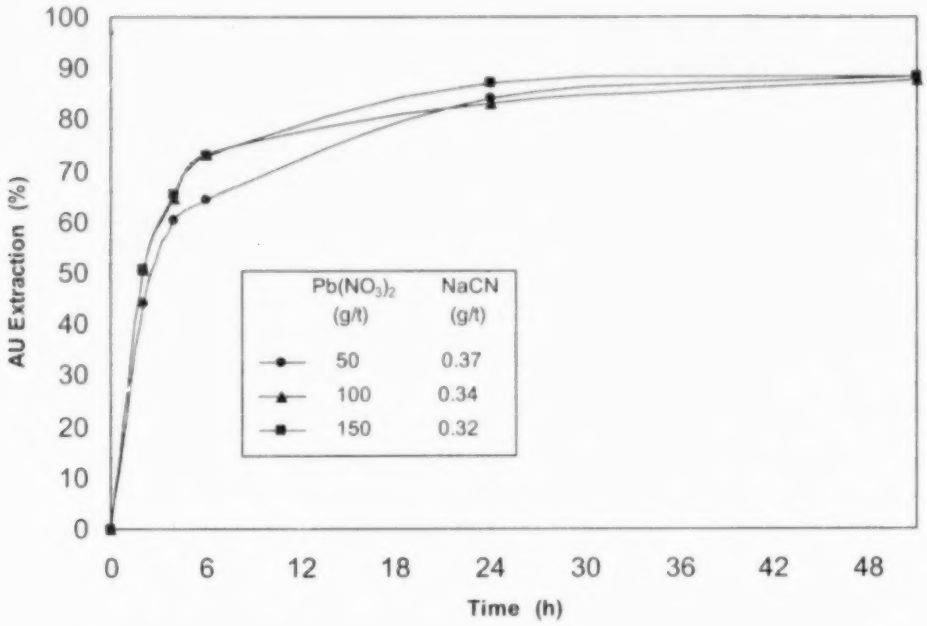

Figure 3: Effect of lead nitrate addition on the leaching of the New Britannia Mine ore. Pre-leaching: pH 11.1, 8 ppm O2, 0.5 h; cyanidation: pH 11.1, 230 ppm NaCN, 8 ppm O_2

The relation between the addition of lead nitrate and the measurement of the reducing power and the concentration of CNS^- is illustrated in Figure 2. Two additional sulphide bearing gold ores were tested and showed the trend is the same i.e. the reducing power decreases with increasing lead nitrate addition. The visual reducing power varied by 60 units whereas the reducing power determined by potentiometric titration varied by about 40 units.

PLANT TRIAL

New Britannia Mine is a gold producer with a CIP mill processing 2200 tonnes per day of slightly refractory ore. The head grade is typically 5 g/t with about 3% of the gold locked in solid solution with the arsenopyrite. To alleviate the effects of sulphides, lead nitrate is added in solution form (19%) as a preleach treatment, at the discharge end of the ball mill. Since its incorporation, the overall gold recovery rose from 89% in 1997 to 94% year to date 2002. Previous work describes the results in details (Healey, Deschênes, Jean and Fulton 2000).

Until now, the control method of lead nitrate consisted of using the gold residue value of the #3 leach tank, an indication of the final tails, and to adjust the lead nitrate accordingly to optimize gold leaching. Lead nitrate addition had to be adjusted in relation to variations in the gold content of the feed. For a period of time, the lead nitrate addition was usually kept constant at 48 g/t until the head grade increased from 4.4 g/t Au to 5.5 g/t Au in July 2001. Since then, it was kept around 73 g/t and could go as high as 97 g/t if a high tail grade was experienced. This large variation in the amount of lead nitrate introduced in the circuit warranted a trial of the technology developed by the consortium project.

The concentration of thiocyanate in the leach solution was monitored using the reducing power measurement with a visual end point. For the tracking period starting July 2002, the lead nitrate addition was kept at a constant while the titrations revealed the shifting level of thiocyanate in the #1 Leach tank. The cyanide levels and gold content of the residue in the #1 Leach tank were also monitored.

To create an efficient database of "base line" thiocyanate levels, titrations were performed four times per day during a 9-hour dayshift initially. It was reduced to twice a shift for the remainder of the two-month trial period once it was established that there were no significant variations of the level of thiocyanate during the 9-hour day.

Some key points needed to be established during the tracking period.

- How is the thiocyanate varying with the gold content in #1 leach tank?
- Is the #1 leach tank gold residue grab sample correlating with the 12-hour composite head grade?
- What is the final tail grade value corresponding to the head grade 50 hours later? and
- How constant is the lead nitrate addition compared to its set point?

Figure 4 shows the #1 leach tank gold residue varying alongside the level of thiocyanate for the tracking period. It illustrates the correlation established in the laboratory between the amount of lead nitrate added in a circuit and the thiocyanate formation. At a constant addition of lead nitrate, a higher concentration of thiocyanate is formed if the sulphur content of the feed increases. There was a day near the very beginning where the lead nitrate was overdosed inadvertently. It can thus be observed that the thiocyanate decreased while the head grade had increased.

On Figure 5, the final tail grade exiting the mill circuit indicated no upsets during the two-month trial period. The gold value in the tails remained constant around 0.27 g/t Au despite the varying head grade. There are two instances of unexplained increases in the tail grade up to 0.34 g/t Au, they were deemed insignificant. The head grade, taken as a 12-hour composite of the cyclone overflow, was compared to the #1 leach grab sample. It varies closely with the #1 leach gold assays taken at the same time as the thiocyanate measurement.

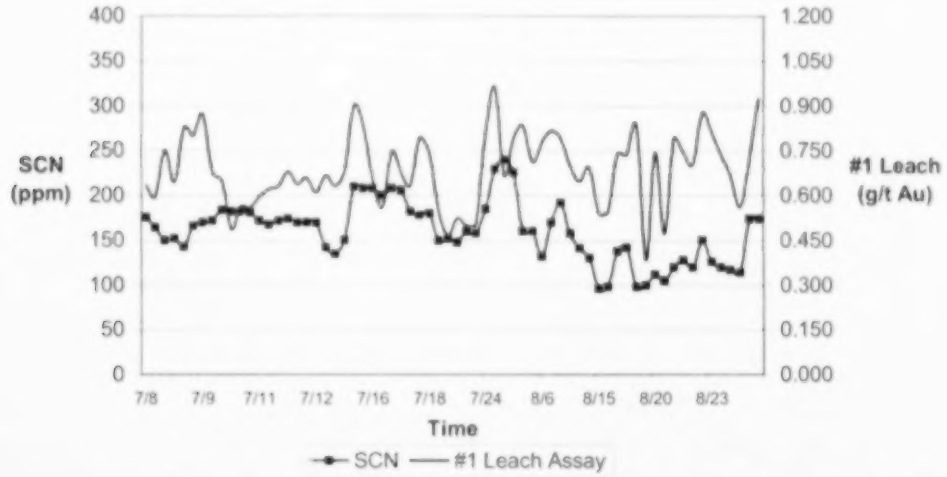

Figure 4: Gold content of the leach residue and concentration of thiocyanate in the first leach tank.

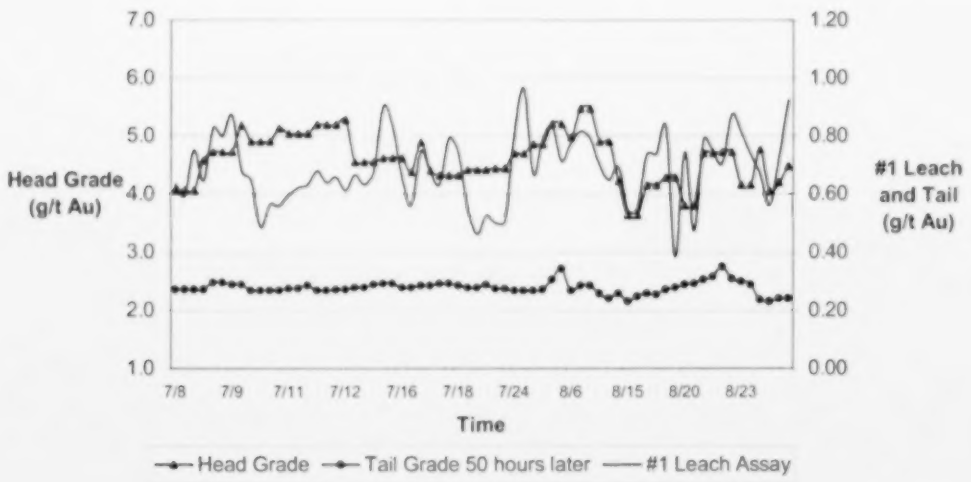

Figure 5: Gold content profile in the leach circuit during the lead nitrate trial (constant addition of lead nitrate)

The actual rate of lead nitrate addition was checked each time a titration is performed. Figure 6 shows the variation of lead nitrate addition even though the set point is constant. This information has to be considered in the interpretation of the data.

The data gathered from the tracking period was sufficient to decide controlling the rate of lead nitrate addition based on the measurement of thiocyanate. The peaks of thiocyanate attained as high as 240 ppm although the tail grade never increased. It indicated that the rate of lead nitrate addition could be decreased until the thiocyanate reached as high as 240 ppm. A control level of 170 ppm was actually chosen, being more conservative.

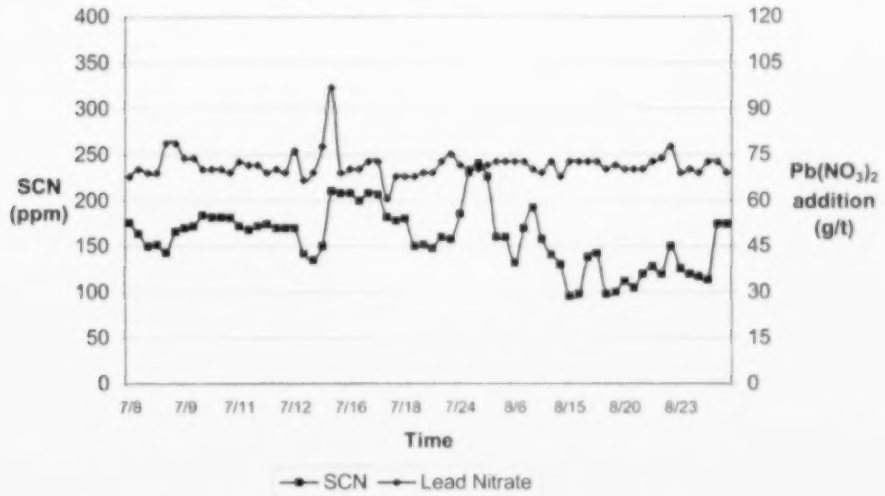

Figure 6: Rate of lead nitrate addition and concentration of thiocyanate

On September 3, 2002, the rate of lead nitrate addition was lowered from 72 g/t lead nitrate to 61 g/t lead nitrate. The decrease of the lead nitrate was carried out slowly since it was unknown how much the thiocyanate would increase. Within the first week it was decreased by 30%, to 48.4 g/t lead nitrate with no increase in the level of thiocyanate and no detrimental effects on gold recoveries. It was expected that the thiocyanate levels would rise, but it was soon found that the thiocyanate levels had not changed because the head grade had also dropped at the same time that the lead nitrate was decreased. It is believed that the grade is related to the sulphide content of the feed although the relationship is not clear. The final tail grade also reflected the lower gold content. See Figure 7 for data from the control period.

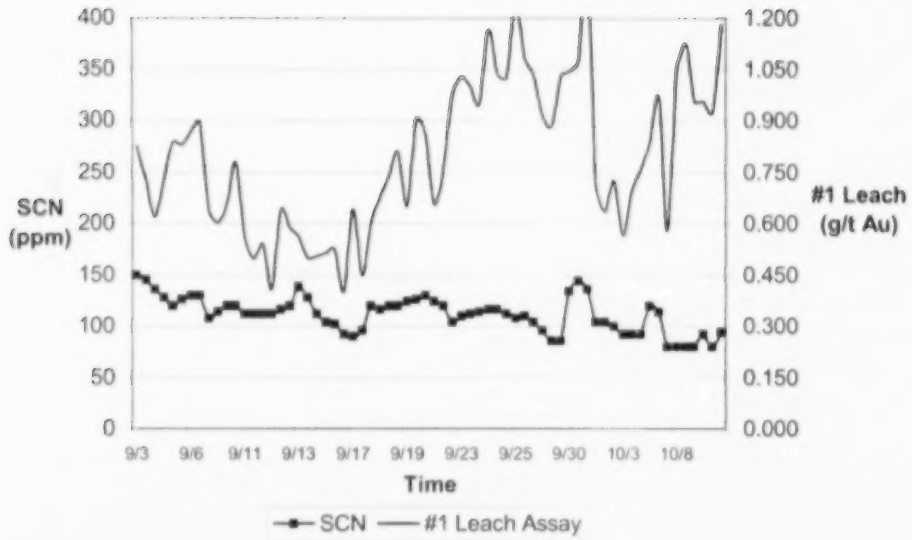

Figure 7: Gold content of the leach residue and concentration of thiocyanate in the first leach tank

A 48 g/t lead nitrate rate was kept from September 9 -18 to evaluate its impact on the circuit such as cyanide consumption increase and higher tail values. None were found other than the cost savings provided by the reduction of lead nitrate. The lower head grade also continued until September 18 at which point the lead nitrate was lowered to 36 g/t. The level of thiocyanate never increased as expected. Instead the head grade started climbing again with no change to the thiocyanate level. This change of behavior remains unexplained. The rate of lead nitrate was increased to 55 g/t until it was confirmed that the final tail residue would not increase for lack of lead nitrate. The tail values did increase but only to expected levels (0.34-0.41 g/t Au). See Figure 8.

The lead nitrate was kept at 55 g/t for a week and a half, and then was lowered to 42 g/t for further investigation (Figure 9). It reveals that the level of thiocyanate may not vary as linearly as first expected. Maybe the "range of variation" changes with each different rate of lead nitrate addition. This would translate into a large database correlating gold residues with various amount of lead nitrate. Therefore, the measurement of thiocyanate would become an indicator of gold content in the #1 leach tank much quicker than pulp assays 24 hours later. The thiocyanate levels will be tracked at various addition rates of lead nitrate.

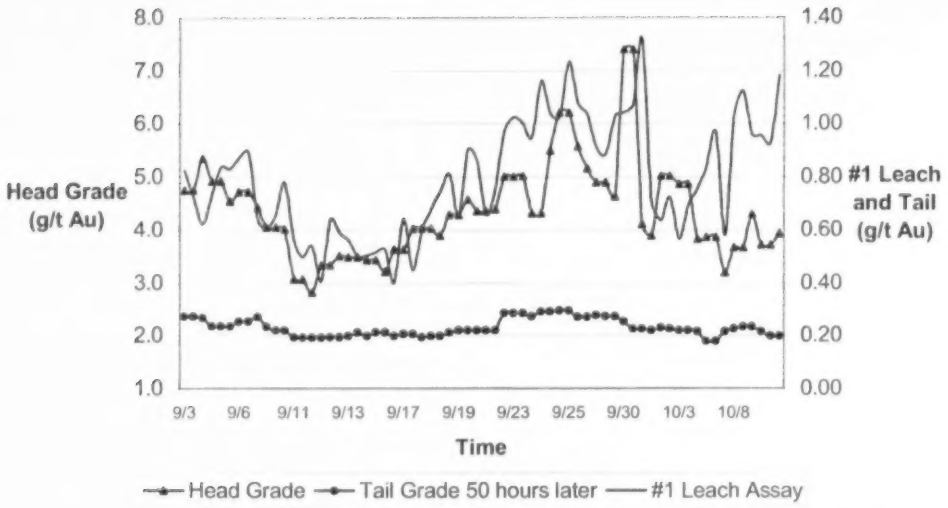

Figure 8: Gold content profile in the leach circuit during the lead nitrate trial (varying addition of lead nitrate).

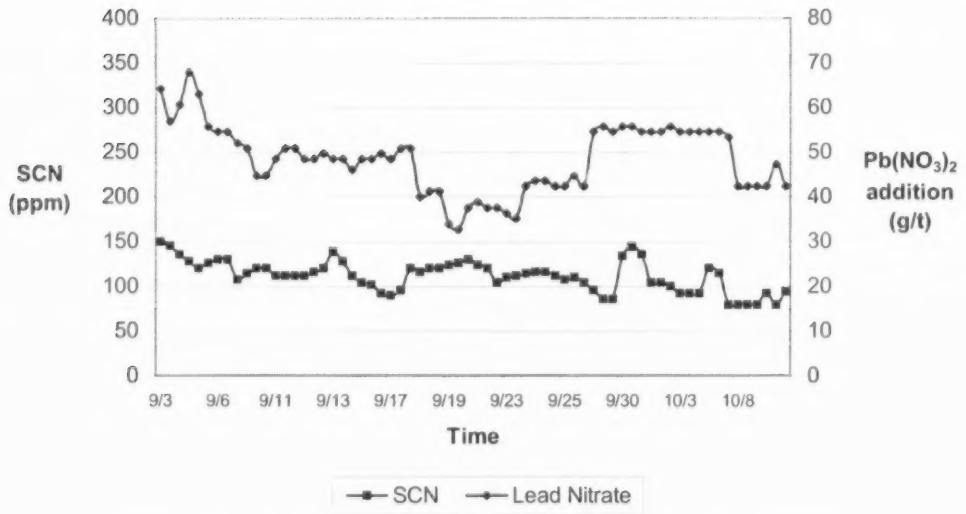

Figure 9: Rate of lead nitrate addition and concentration of thiocyanate

CONCLUSIONS

The plant trial on the assessment of the use of thiocyanate to control lead nitrate addition led to cost savings on reagents at the New Britannia Mine. The lead nitrate addition was reduced by 50%. No decrease of gold extraction was experienced during this trial. The relation between the

gold content of the feed and its sulphide content should be established. Laboratory results indicated that for a constant sulphide content of the feed, the increase of lead nitrate reduced the concentration of thiocyanate formed in the leach solution. The measurement of thiocyanate will continue to be used until a robust database can clearly predict the rate of lead nitrate addition. Then the titrating responsibility will be passed to the operators for 24-hour control.

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